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THE INTELLECTUAL FOUNDATIONS OF SYSTEMS ANALYSIS

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Introduction: Policymakers Versus Secretive Bureaucrats

In recounting the intellectual foundation of any subject, one should bear in mind that most advanced thought can be traced to the ancient Greeks. This claim especially applies to systems analysis. Although they did not possess the formal tools of systems analysis, many Greek thinkers personified its essential quality: Socrates, in particular, persistently asked questions and relentlessly questioned assertions. However else systems analysis is defined, question-raising and finding rational answers to at least some of them is what the subject is about. Now this is not new as a feature of decisionmaking. But what was new--and what came to be called systems analysis during the lifetime of many of us--was that high-level government policymakers at key junctures revealed themselves to be the question-raisers. However, to ask relevant questions so as to evoke useful answers is neither simple nor easy. Indeed, when a senior government policymaker asks a tough question, a simple or straightforward answer is seldom forthcoming. This is because, usually, the question must be directed to, and answered by, a bureaucracy.

Although bureaucracies are composed of able and dedicated people and are valuable social resources (e.g., the officer corps), they develop at least one skill to a high degree: that of obfuscation. As Max Weber reminds us, "every bureaucracy seeks to increase the superiority of the professionally informed by keeping their knowledge and intentions secret."[1] The resulting monopoly of knowledge can be

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[1]See Max Weber, "Bureaucracy," translated from *Wirtschaft und Gesellschaft*, by H.H. Gerth and C. Wright Mills in *From Max Weber: Essays in Sociology* (New York: Oxford University Press, 1946; first

used by agency officials to resist change, protect prerogatives and budgets, and foster a favorable public image. In a political (i.e., public sector) context, these provide a basis for an independent constituency. For a public official, one's constituency is the counterpart of property to a private person. Changes in an agency's way of doing business can upset constituents. This is one reason why officials resist it. Thus an elected or politically appointed policy-maker who asks tough questions and wants useful answers needs a staff to facilitate his search. Such a staff will probably employ the techniques and, especially, the spirit of systems analysis. Viewed in this context, systems analysis was a modern development if not social phenomenon, for reasons I shall now try to recount.

For most of recorded history, the principal government resource-using activity was that of military affairs. Most senior public officials were themselves men of military experience if not considerable accomplishment. Nor did military organization or technology change very quickly. There was, in fact, little that specialists could be secretive about toward political masters like Hadrian, Trajan, Frederick the Great, or Napoleon. This condition began to change, however, with the almost simultaneous emergence of advancing technology that characterized the later phase of the Industrial Revolution, and representative government. Increased technicalities enabled specialists to be secretive toward their political masters. The modern bureaucrat was a consequence of these major technological and institutional changes.

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published in 1922), pp. 232-233. One should not underestimate a bureau's ability to dissemble. Perhaps the most sensational example was provided by the French Army in the Dreyfus case. But such bizarre instances should not distract attention from the more serious and pervasive "information failure" that results from agencies not pursuing lines of inquiry suspected of being harmful to budgets. Potentially critical activities, like operational testing or similar experimentation, therefore, either must be directed and overwatched from "outside" the bureaucracy, or else special incentives must be created to induce an agency to do the needed testing or to acquire the needed information. Dealing with this information problem is perhaps the major challenge that systems analysis, if not public policy analysis, faces.

Although it is true (as Weber points out) that "the power position of a fully developed bureaucracy is always overtowering,"[2] technological change also afforded a channel by which "outsiders" could penetrate secretive bureaucracies. Thus after personally test-firing a Spencer repeating rifle on the Ellipse, President Lincoln saw to it that enough repeaters were procured (over the objections of the Army's Ordnance Department) to equip Sheridan's cavalry. However, Lincoln's action was more one of hard-nosed Test and Evaluation (of which we have precious little today) than analysis. It was not until the early 20th century that an example was presented of how thoroughly an outsider could use a technical channel to suggest major changes in military tactics and force design.

The British Invention of Operational Analysis and World War II

In 1916, a mere dozen years after the Wright brothers flew the first airplane, a member of an advisory committee to the British military air establishment was able to publish a treatise entitled *Aircraft in Warfare: The Dawn of the Fourth Arm.*[3] The author, F.W. Lanchester, has been memorialized in the literature on operational research as the discoverer of the "n-square law" of combat, a formal and elegant presentation of the age-old military axiom known as the "principle of concentration of force." The real significance of his work, however, lies not in his mathematical model, but rather in his illustration of how an imaginative engineer could assist military planners and acticians. His book brims over with ideas on how aircraft might be employed in military operations, and how their effectiveness could be improved by technical changes or such modifications as arming them with machineguns. Here was a harbinger of how the airplane, as a technical channel, was to facilitate outsider penetration of the military establishment.

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[2] *Ibid.*

[3] London: Constable and Company, 1916.

With the rise of Hitler and German rearmament, British policy-makers and military-force planners began to face up to the prospect of England's being bombed. Air defense, particularly better ways for detecting attacking aircraft, became a matter of high priority. To cope with the detection problem, the government and the RAF turned to the scientific community.[4]

The British had, during World War I, experience with employing scientists to address technical problems that related to war. By 1918, partly in recognition of the fact that Germany made technical progress in weaponry with the aid of scientific endeavor, a Department of Scientific and Industrial Research was formed, which had a charter to operate in both civil and military fields. In 1919, the Air Ministry created an aeronautical research committee to advise the Secretary of State for Air upon "higher matters of research."[5] Until 1935, this committee was mainly composed of members of the aircraft industry. A reorganization in 1935, however, changed its main composition to that of scientists from government departments and universities. Nevertheless,

[4]There are numerous sources that recount the story of radar, its associated spawning of operational research, and the subsequent growth of operational research. The best accounts are Air Ministry, *The Origins and Development of Operational Research in the Royal Air Force* (London: Her Majesty's Stationery Office, 1963); and Sir Robert Watson-Watt, *The Pulse of Radar* (New York: Dial Press, 1959). For a highly relevant discussion of higher-level policy making (and politics) bearing upon the air-defense problem in pre-war Britain, see Frederick, the Earl of Birkenhead, *The Professor and the Prime Minister* (Boston: Houghton Mifflin Co., 1962), esp. pp. 117-219, a sympathetic biography of one of the most controversial figures involved in the British war effort--F.A. Lindemann (later Lord Cherwell), who was Churchill's scientific adviser. With reference to the air-defense problem, see also Ronald W. Clark, *Tizard* (Cambridge, Mass.: M.I.T. Press, 1965), esp. pp. 105-163. Although the British deserve credit for the "invention" of radar as an operational system, discovery of its narrower technical underpinnings were not exclusively British. For a good account of developments in other countries, some of which were superior to those of the British, see Dulany Terrett, *United States Army in World War II: The Technical Services, The Signal Corps: The Emergency (to December 1941)* (Washington. D.C.: Office of the Chief of Military History, Department of the Army, 1956), pp. 35-48.

[5]*Operational Research in the RAF*, *op. cit.*, p. 2.

throughout the entire period prominent academic scientists--including F.A. Lindemann and H.T. Tizard--were affiliated with the committee.[6]

Toward the end of 1934 an ad hoc committee was set up "to consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defense against hostile aircraft."[7] Its chairman was H.T. Tizard. Shortly after formation of the Air Ministry's committee, Parliament set up an Air Defense Subcommittee of the Committee of Imperial Defense, to be chaired by the Secretary of State for Air[8] and with a function to coordinate interservice and interdepartmental activities bearing upon air defense. Tizard was made a member of this latter committee.[9] Under Winston Churchill's auspices, F.A. Lindemann was made a member of the Tizard Committee. (Churchill was a minority member of Parliament at the time.) The stage was set for a bitter struggle between Tizard and Lindemann that subsequently evoked, if nothing else, much acrimonious comment on personalities, interwined with philosophy on the use of and a role of scientists and intellectuals in government.[10]

As a result of the ad hoc committee's work, resources were made available to pursue the development of radar. Robert Watson-Watt (later Sir Robert), who had been doing research on radio communications, was installed at a government-provided facility to develop a new means of detection. Progress was rapid, and in 1935 a workable radio-ranging and detection device was invented. The next problem was how to use it effectively. The RAF obtained a larger facility for Watson-Watt and his colleagues and began to lay on field-type experiments--employing

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[6] *Ibid.*

[7] Quoted *ibid.*, p. 3.

[8] For an account of the higher-level political travail that led to the after formation of the parliamentary Subcommittee, see *The Professor and the Prime Minister, op. cit.*

[9] *Ibid.*, p. 3.

[10] See, especially, C.P. Snow, *Science and Government: The Godkin Lectures at Harvard University, 1960* (New York: New American Library, 1962). As a balance to Snow's appraisal of Lindemann, one should read Birkenhead's *The Professor and the Prime Minister, op. cit.*

aircraft to simulate operations--in order to gain data on the operational behavior of the new equipment. The civilians participated in the design of the experiments, reduced and interpreted the data, and recommended how to use and deploy radar. In the process, engineers obtained insight on how to modify the equipment so as to improve operational effectiveness. This activity was a joint affair, or an operating partnership, between military operations officers and the civilian scientists. The scientists became privy to knowledge about operations; the military officers acquired technical expertise about the equipment. Hence, operational research was born. The result of this seminal effort was the deployment, by the outbreak of the war, of twenty radar stations in Great Britain and three stations overseas that could detect aircraft flying at medium altitudes at a range of 100 miles.[11]

Critical to the "invention" of operational analysis was the idea that scientists work closely with the operators. For achieving this objective, credit is due to Lord Swinton, who became Secretary of State for Air and who indicated to the Chief of the Air Staff, "I want no secrets from these men; they will be as much a part of the Operational Staff as you and your staff are."[12] As Watson-Watt explained, "The length of the arm which formerly held the staff user, and even the field user at a distance from the technical developer" had not only been "bent to a shorter effective length," but had "been curved into a cordial embrace."[13] It was indeed something new. That civilians came to have access to the workings of one portion of a military bureaucracy was largely due to high-level, civilian policymakers who were greatly worried about the air-defense problem. Also relevant was that Fighter Command, not the dominating Bomber Command, was the object of this initial effort. Fighter Command did not enjoy the favored budget position within the RAF. It was therefore apt to be more receptive to getting help from outsiders.

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[11] Denis Richards, *Royal Air Force 1939-1945, Vol. 1, The Fight at Odds* (London: Her Majesty's Stationery Office, 1953), p. 25.

[12] Quoted in *The Pulse of Radar, op. cit.*, p. 278.

[13] *Ibid.* pp. 287-79.

After the Battle of Britain the integration of civilian scientists with military-operations officers in teams, functioning in a military staff, extended rapidly throughout the British military establishment, and especially the RAF. Radar and related electronics items were the initial and principal focus of these efforts. Successively, RAF Coastal Command and the Navy employed such teams to address antisubmarine warfare problems. RAF Bomber Command acquired operational research staffs for assistance in navigational and bombing problems.[14] Overseas commands acquired operational research sections. The scope of the intellectual efforts also broadened to encompass such subjects as fuse settings for ordnance, bomb loads and bombing patterns, targeting doctrine, shipping and submarine search problems, and--as applied to naval operations--convoy design. Thus civilian scientists acquired increasing knowledge of the sphere of the operations section of the military staff system. Operational research analysis sections also began to filter downward in the military hierarchy and appear in the headquarters staffs of subordinate commands.

Extension of operational analysis from the RAF to the British Army and Navy followed after the outbreak of war. In 1940, Gen. Sir Frederick Pile, commander of the antiaircraft command, appointed P.M.S. Blackett as his scientific adviser. (Blackett was a charter member of the original Tizard Committee.) He formed a mixed team of scientists that addressed aircraft acquisition, employment of gun-laying radars, gun-site location, and related antiaircraft problems. Under the War Office, elements of this group severed their association with the air defense establishment, and expanded its scope and created sections to treat the entire range of land-warfare problems, to include infantry, artillery, and antitank gunnery. During 1942 and 1943, sections worked in the field with land forces operating in the Middle East, Italy, and India.[15] The pattern of field work was repeated on an extensive and

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[14]For the account of the expansion in the RAF, see *Operational Research in the RAF, op. cit.*, p. 43-91.

[15]*Ibid.*, pp. 40-41.

highly professional scale with the British (and in some instances American) land forces in Northwest Europe. The report of the 2nd Operational Research Section with the British 21st Army Group, covering the period of June 1944 to July 1945, contains a number of gems bearing upon combined-arms operations. In land-warfare operational research is not as clean cut as it is with air or naval war. The method of inquiry is like that of criminal investigation. The researchers follow the scene of an action, drawing upon operations orders and commanders' after-action reports as much as possible. But the main effort consists of measuring engagement ranges; examining scars upon tanks or vehicle carcasses to determine what actually made the kill; counting spent cartridge cases and hastily dug graves; interrogating prisoners, farmers, and one's own soldiers; and from these and other sources gathering enough statistics to learn what happened and to verify or refute hypotheses.

In early 1942, the Admiralty established a Department of Operational Research, which was headed and formed by Blackett. (He had also played a similar role for the RAF Coastal Command.) Unlike operational research activities of the RAF and the Army, the Admiralty's endeavors did not extend to field commands, but were centered in the headquarters.[16]

The American Copy

Operational research extended to U.S. forces mainly through interaction with the British. In the early part of 1942, General Spaatz requested General Arnold to provide the Eighth Bomber Command "a group similar to those attached to elements of the RAF."[17] One suspects that Spaatz's motivation to acquire the capability was in part stimulated by

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[16] *Ibid.*, p. 41. For an account of the application of operational-research techniques to the submarine and shipping phases of the war, intertwined with his views on the methodology of operational research and insights about some of the higher-level bureaucratic issues related to the British strategic bombing effort, see P.M.S. Blackett, *Studies of War: Nuclear and Conventional* (New York: Hill and Wang, 1962), pp. 169-234.

[17] Florence N. Trefethen, "A History of Operations Research," in Joseph McCloskey and Florence Trefethen (eds.), *Operations Research for Management* (Baltimore: Johns Hopkins Press, 1954), p. 13.

bureaucratic requirements with regard to their RAF counterparts. American and British air doctrine differed in important respects on tactics, including targeting. One can picture a meeting between senior officers of the two air forces. The British have with them their "scientist" (who, of course, sits quietly against the wall along with other staff seconds--not at the table with the principals). Straightaway, one side has gained an element of "one upmanship," which is intolerable to the opposite side. For this reason General Spaatz's request was no doubt urgent. However, by October 1942, General Arnold recommended to all Air Force commands that they acquire the capability of operational research.[18] The Air Force history notes that Arnold "became fond of admonishing his staff that 'the long haired boys' could help."[19] The scope and scale of employment of analysts to address operational problems proceeded rapidly. As the air offensive in Europe got underway a joint Anglo-American team emerged (which administratively was under the British Air Ministry) that addressed targeting and bomb-damage assessment.[20] In much the same way, the U.S. Navy acquired an OR capability as a result of its need to work with the Royal Navy in their joint effort against German submarines.

Like the British antecedents of operational analysis, the wartime evolution of the American counterpart had its foundation in the employment of civilian scientists and engineers to address the purely technical aspects of war. Although a sharp distinction exists between operational analysis on one hand and technical research and development on the other, there is an important common ground with regard to the two activities. Some attention to these points is relevant to the understanding of differences between British and American developments in the use of scientists and intellectuals.

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[18] *Ibid.*

[19] W.F. Craven and J.L. Cate (eds.), *The Army Air Forces in World War II, Vol. 6, Men and Planes* (Chicago: Univ. of Chicago Press, 1955), p. 42.

[20] *Operational Research in the Royal Air Force, op. cit.*, p. 42.

As part of the effort to prepare for war and the belief that the United States might be technically lagging in the field of weaponry, the National Defense Research Committee (NDRC) was created in June 1940. There were two underpinnings for this Act. First, there was the National Academy of Sciences, created by Congress in 1863, which by Executive Order in 1918 was empowered to create a National Research Council. The Academy was composed of prominent physical and life scientists, elected by the professionals themselves. Second, there was the Council of National Defense, created in 1916 and composed of the Secretaries of War, Navy, Interior, Agriculture, Commerce, and Labor. As a government instrument, it was authorized to create committees of "specially qualified persons." The NDRC was its creation. Initially, it was composed of eight members--two each to be selected by the Secretaries of Navy and War, the President of the National Academy of Sciences (who was also President of Bell Telephone Laboratories), and the Patent Commissioner, and four members at large, who included Vannevar Bush and James Conant.[21] The Committee promptly created five divisions, containing numerous sections, to treat the many applications of technology to war. These sections dealt with highly specific technical matters, such as "paint removers," "pyrotechnics" as well as "propulsion," and "proximity fuses for shells."[22] The divisions and sections were chaired by persons drawn from both universities and industrial firms. The Committee also had authority and funds to undertake research contracts.

A year after the establishment of NDRC, the President, by Executive Order, established the Office of Scientific Research and Development (OSRD). It was placed in the Office of Emergency Management of the Executive Office of the President.[23] OSRD was to stress the development

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[21] Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development* (Boston: Little, Brown, 1948), pp. 7-9.

[22] *Ibid.*, pp. 10-11.

[23] The Executive Office of the President was established before the War by President Roosevelt. In 1939 he issued a Military Order that moved the Joint Board of the Army and Navy, which had the responsibility to coordinate strategic plans; the Army-Navy Munitions Board, which controlled procurement programs; and the civilian agency responsible for

phase of research and development, to ensure coordination with regard to some government scientific activities over which the National Defense Research Committee had no cognizance, and to stimulate research in military medicine.[24] Although officially it was a staff by virtue of being in the President's Executive Office, the frequent use of the verbs "initiate" and "support" in the Executive Order suggests that it was intended to play an activist, if not a line, role. Subsequent Executive Orders allowing OSRD to acquire and dispose of property and to function under the same legislation that governed the Army and Navy with regard to contracting reinforced this point.[25] Vannevar Bush was made Director of OSRD. The NDRC was designated to function in an advisory capacity to OSRD. Thus, within a year, two important and mutually supporting steps were taken. First, a mechanism was created to establish communication channels between academic and industrial scientists on one hand and the government on the other. Second, the bureaucratic apparatus was created that had the power both to implement the advice of the scientists and, equally important, to exert a force that could cut across and through the diverse bureaucratic fiefdoms, especially those that comprised the Technical Services and Bureaus of the War and Navy Departments.

Through OSRD auspices scientists and engineers fanned throughout the military services to work in laboratories and arsenals. The emphasis was on developing weapons and quickly getting them into operating units. Such items as the "Bazooka" (or the combination of a rocket and shaped or hollow charge that served as an infantryman's anti-tank weapon), aircraft rockets, the proximity fuse, radar-bombing, and specialized amphibious vehicles were some of the developments. To expedite deployment of these new systems and to correct flaws that

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military production into the Executive Office. Since the Army Chief of Staff and the Chief of Naval Operations were members the Joint Board, they became directly responsible to the President, rather than indirectly through the Secretaries of War and Navy. For an account of this change, which facilitated the decisive personal role President Roosevelt played in shaping U.S. World War II strategy, see Kent Roberts Greenfield, *American Strategy in World War II: A Reconsideration* (Baltimore: The Johns Hopkins Press, 1963), pp. 49-84.

[24] *Organizing Scientific Research for War, op. cit.*, pp. 35-37.

[25] *Ibid.*, p. 38.

appear whenever new systems enter the field, OSRD created in November 1943 an Office of Field Service. The Administrative Order establishing this Office emphasized the need "to make the most effective possible use of developments . . . and minimize the effectiveness of any such developments made by the enemy, especially those in combat use."[26] Operational research was listed first as one of the services to be provided. The Director of the office was also authorized to employ and train personnel for the activities. Since the function was both delicate and important, Karl T. Compton, President of the Massachusetts Institute of Technology and a member of NDRC, was named Director of the Office of Field Services.[27]

Employing scientists in the field presents delicate problems because it entails mixing individuals of different backgrounds and who have different responsibilities. Military officers are responsible for operations; scientists and engineers in the field view operations as a means to an end, or sources of data. The question-raising and probing necessary for the scientist to perform his task, if not put tactfully, can easily be construed by the military operator as criticism of his decisions or performance. Tension between civilian and military subcultures, especially in time of war, is increased by the fact most uniformed military feel superior to if not contemptuous of civilians, even though the latter may wear fatigues and combat boots in the field. Finally, civilian scientists, through their attachment to a higher headquarters or through their spontaneous and informal information channels, can cause information regarding activities in a local setting to be made known in higher quarters that can prove troublesome to a local commander. For these reasons, the injection of "combat scientists" into operating commands was difficult.[28] Karl Compton had to be a missionary as well as a scientist.[29] It is significant that his

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[26] *Ibid.*, p. 129.

[27] For a brief summary of the office's activity, see *ibid.*, pp. 128-150. For a more detailed account see, Lincoln R. Thiesmeyer and John E. Burchard, *Combat Scientists: Science in World War II* (Boston: Little, Brown, 1947).

[28] *Ibid.*, pp. 9-11.

missionary effort was primarily directed to the Pacific theater of operations. In that theater there was no British counterpart to provide the American military either an example or a bureaucratic incentive to acquire operational-research capability.

For these reasons, operational research did not become as extensive throughout the American World War II military establishment as it did in the British. "Combat scientists," on the other hand, were nevertheless used extensively in all theaters to perform "field engineering" (which was also part of the Field Service's charter) to address highly technical problems, such as coping with fungi in the South Pacific, which affected such diverse equipment as combat boots and radio sets. For these reasons, the main accomplishments of the American operational-research endeavor centered on Atlantic convoy operations and strategic bombardment. In these areas there was either a requirement to deal with the British or the precedents established by the USAAF or both. Apart from the wartime contribution of these men, whether "combat scientists" who dealt with technical problems or operational analysts, there was created a group of scientifically trained people who acquired a feeling for and interest in military operations and planning. Members of this group in turn were to provide the leadership and nucleus of such post-war organizations as RAND, the Army's Operations Research Office, and the Center for Naval Analysis; as well as to introduce the methods of OR into military technical establishments like the Army's Ballistics Research Laboratories and the Naval Ordnance Test Station.

It is interesting to note that in the American idiom "operational" research became "operations" research. It is not known why and how the adjective became an attributive noun. There are two plausible explanations. One is that Americans are careless about English grammar. A more suggestive one is offered by Watson-Watt:[30] The "s' instead of the "al" implies that the activity is part of a traditional military-operations staff section. In this setting civilians are subordinate to the military. Some way had to be found to arrest the growing influence of civilians in a traditional preserve of the professionals or, perhaps,

[29] *Ibid.*, pp. 12.
[30] "*The Pulse of Radar, op. cit.*, pp. 324-325.

to mollify the warrior caste by suggesting or signaling that the activity would be under its control.

Back to Britain: Churchill and Cost Effectiveness Analysis

The rise of operational research is recounted by historians as being a consequence of the payoff provided by radar in the Battle of Britain. However, the question should be raised why the accomplishment of Watson-Watt and his group did not remain a singular event? Given that operators jealously preserve the secrecy of their expertise, we must conclude that success in coping with one technical-operational problem is not sufficient to transform precedent into an institution. Rather, the stress inherent in mingling military and civilian personalities and its potential for destroying the secrecy a bureau seeks to maintain could have caused the relationship to be terminated after the air-defense problem was treated (with appropriate military citations awarded, of course, to Watson-Watt and his civilian colleagues). But this did not happen. Instead, the use of mixed teams of civilian scientists and analysts, and military officers to address operational problems spread throughout all part of the British military establishment.

For these reasons, World War II operational research was a major institutional phenomenon. Because it confronted forces that operate against openness and clarification, one must look beyond the single event of the invention of radar as an operational system. Other conditions and circumstances must have prevailed for operational research to emerge. These circumstances were the result of the British setting and the personal leadership qualities of Winston Churchill, factors that generated the precedent for modern cost-effectiveness analysis.

The World War I Western Front stalemate presented allied leadership a cruel strategic-tactical dilemma. The soldiers could not develop or revise infantry tactics quickly enough to cope with the machinegun in a strategic context that presented very high troop densities; allied policymakers--particularly the French--were unwilling to revise strategy in a way that might suggest acceptance of German acquisition of any newly acquired territory. The British tried to cope with this dilemma, and Churchill had a hand in both a strategic and a tactical approach. The amphibious Gallipoli operation was advocated by Churchill to break the deadlock. Unfortunately, the operation was bedeviled by faulty staff work, an unwarranted faith in naval firepower, and failure to load ships to facilitate amphibious operations. Indeed, it was argued that "foot-dragging" at high levels of the British military hierarchy caused the operation's failure. By the time it was being discussed, the high-level military staffs had come to be dominated by "Westerners," or people who viewed the Western front as the decisive theater of operations. Partly, this kind of bias arises from loyally carrying out of the normal tasks of supporting the field troops and their commanders. But whatever the motivation, implementation of the operation was poor.

Back in England, a new weapon termed the "tank" (the word was chosen for intelligence purposes to mask what was being developed) appeared to have tactical promise. As with the Gallipoli campaign, Churchill had an association with the tank program. During his tenure as First Lord of the Admiralty, the Naval Air Service undertook the development and procurement of armored vehicles to provide perimeter security at naval airfields located in Belgium. It was felt by many that Field Marshall Haig lacked imagination in their use, however, and their potential was not fully exploited.

These experiences gave Churchill considerable cause to brood during those interwar years when he was absent from active government life. If they were not the basis for this concern, they at least reinforced his professed distrust of "the bureaucracy."

When Churchill entered the wartime Chamberlain government as First Lord of the Admiralty, he brought with him his personal scientific adviser, F.A. Lindemann, an Oxford physicist. One of Lindemann's first items of business, undertaken with Churchill's blessing if not by his instruction, was to create a small staff that came to be named the S-Branch ("S" for Statistics). The function and character of this group is central to our story.[31]

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[31]This and the following section draws upon R.F. Harrod, *The Prof* (London: Macmillan, 1959); and also G.D.A. Macdougal, "The Prime Minister's Statistical Section," in D.N. Chester (ed.), *Lessons of the*

This branch treated questions addressing the entire range of issues related to resource allocation in wartime, including the interaction between military and civilian "requirements." (The record shows that Lindemann, the scientific adviser, spent about one-third of his time on technical and scientific problems, with the remainder devoted to those of resource allocation.)[32] His staff numbered about twenty, including clerks and typists. Its core comprised half a dozen young economists. The economists were recruited by R.F. Harrod, an Oxford economist colleague of Lindemann, who was also a member of the staff.

The motive for creating such a staff was twofold. The ostensible reason was to enable Churchill to discharge his function in the cabinet on matters that the cabinet as a whole had to treat. This required a knowledge of the reports of other ministries, particularly of critical knowledge that might be useful in any interministry struggle. The second reason, used by Lindemann in recruiting his staff, was the hope that Churchill would become Prime Minister. Knowledge of the entire range of government resource-using programs could serve Churchill both in attaining the number one position and in discharging its functions more fully and quickly should it be attained.[33]

It was unclear, at least for all the concerned parties such as Harrod, whether or not, as a Prime Minister, Churchill would "wish to have around him a band of critics, who precisely because they were not fully merged into the general machinery of government, would give him an independent judgement."[34] Whatever doubts there may have been on this point (and whatever understanding there may have been between Churchill and Lindemann) were resolved when Churchill retained his "band of critics" upon becoming prime minister.

British War Economy (Cambridge: Univ. Press, 1951), pp. 58-68. Both Harrod and Macdougal were members of the section. I have also drawn on personal correspondence with Professor Harrod.

[32] Macdougal, *op. cit., p. 60.*

[33] Harrod, *op. cit.*, p. 186.

[34] *Ibid.*, pp. 186-187.

The reason Churchill created and retained an independent staff to perform critical analysis lies in bureaucratic behavior, and is revealed by descriptions or some of the problems the Statistics Branch addressed. Each bureau or ministry is a fiefdom, which struggles with every other bureau for scarce resources. In time of war each bureau takes a pessimistic view of the problems or threat it must cope with, so as to lay claim to resources.

Thus, the Air Ministry in 1940-41 estimated the German air order of battle to be about 50 percent greater than it actually was. This result followed from comparison of the number of RAF aircraft in operational squadrons with the total number of aircraft that intelligence sources detected on the German side. The latter's resources therefore included first-line aircraft used for operational training, aircraft under repair, and other leakages. The resulting issue was resolved by Lindemann when he personally interrogated some German prisoners. Upon clarification of what the numbers meant, which was a bureaucratic defeat for the Air Ministry professionals, additional aircraft were transferred from the defense of England to play a decisive role in the 1941 North African campaign.[35] In such fashion, the experts were to be confounded, exasperated, and infuriated many times. How could the Army, which with other ministries was advocating increased austerity for the civilian sector, justify both its stocks of ten pair of trousers per man and an increased rate of production?[36] Did it make sense to procure antiaircraft munitions in quantities whose cost would exceed the damages an unopposed German air force could inflict?

In response to the Army's request for conscription of additional manpower, Churchill in a two-page memorandum to his Secretary of State for War summarized the essential bureaucratic principles of land-force organization that led to great discrepancies between "what used to be called bayonet or rifle strength ...'the staple of the Army,'" and total manpower and closed by suggesting that at least a million be "combed out

[35] *Ibid.*, p. 3-5.
[36] *Ibid.*, p. 206.

of the fluff and flummery behind the fighting troops, and be made to serve effective military purposes."[37] Numerous questions affecting the use of shipping, encompassing turnaround times at docks and alternative back haul routes and cargos, were raised.

While he and his staff infuriated ministries on resource allocation issues, Lindemann also managed to exasperate military officers and scientific peers in operational analysis, on operational, equipment, and tactical issues. Among these was the allocation of heavy-bomber resources to targets, and the intelligence appraisals of and countermeasures against German development and deployment of the V-1 and V-2 missiles.[38]

Churchill and Lindemann therefore deserve credit for being the "inventors" of cost-effectiveness or systems analysis as an integral part of the government decisionmaking process. The problems addressed were those of getting the most efficient use of resources. They also ensured that operational research was institutionalized in the military services.

It is likely that the activity that grew out of Watson-Watt's endeavor would have withered away because of the incentives the bureaus have for preserving secrecy and the natural inclination of operators to resist any question-raising tendency by outsiders. However, Churchill vigorously and extensively used the offerings of his personal staff to "shake up" the bureaucracy. The emphasis was on quantitative relationships, and often the arguments implicit in the question raising were based on a mastery of highly technical considerations. The bureaus and ministries, therefore, had a strong incentive to acquire their own expertise, if only for bureaucratic self-defense much in the same manner our own military services followed the Office of the Secretary of Defense when Secretary McNamara created and used a systems analysis

[37] Winston S. Churchill, *Their Finest Hour: The Second World War* (Boston: Houghton Mifflin Co., 1949), pp. 695-697. This particular memorandum may not have been a creation of the staff, since Churchill himself was highly knowledgeable about military affairs. It is likely, however, that he laid out the general idea, and the staff developed the quantitative estimates.

[38] Harrod, *op. cit.*, pp. 198-199.

staff. Since the RAF had the basic elements of operational research capability, it could better cope with the Prime Minister's arguments. In the ongoing bureaucratic struggles, the other military services were thus well advised to acquire their own operational analysis capability, much in the same fashion that the USAAF felt motivated to follow the RAF's lead.

Conclusions

It is evident that the British origin of systems analysis closely followed that of operational analysis. Both had a root cause in a rapidly changing technology. In Britain both OR and the cost-effectiveness analysis practiced by Churchill's staff focused on how to employ technology in a constrained rather than a mindless way, as was illustrated by the resources the Germans squandered on weapons like the V-1 and V-2. In the British case (and the American one as well) it took high-level civilian backing to enable civilians to penetrate the normally secretive military bureaucracies. It is worthwhile to note that nothing like this happened in Germany. Although the German military used "scientists," the latter were never allowed to become familiar with or privy to operations. This perhaps reflected the fact that the German officer corps, if nothing else, possessed superb tactical and operational skills, and thereby felt there was little to be learned from civilians or technicians. Finally, the World War II operational analysis was strongly empirical: People sought to understand military operations, and to gather quantitative data about them. This foundation provided the empirical basis for much of the work done by Churchill's "S-staff."

With respect to the future of systems analysis in the U.S. military establishment, it is relevant to note that very little operational research of the type conducted during World War II is in fact performed today. The difference between the World War II endeavor and contemporary activity is one of methodology, with the former being heavily empirical and experimental. Contemporary military "operational research" in the United States consists overwhelmingly of theoretical model building.[33] One response to this complaint is that it requires a

[33]For a description of this condition see J.A. Stockfisch, *Models, Data, and War: A Critique of the Study of Conventional Forces* (Santa Monica, Calif.: The RAND Corporation, R-1526-PR, March 1975).

war to do empirically based operational research. But a counterargument is that operational testing can be done in peacetime by means of instrumented field trials and structured experiments. Such testing could provide weapon designers badly needed information about whether and how higher technical performance of new systems can provide improved operational effectiveness or combat utility. It can be argued that the weapons procurement process is "out of control" because of an implicit but contestable assumption that higher technical performance is equivalent to higher combat utility. Operational testing can also provide insights about tactics, and crew selection and training. If enough such testing were done, we would be able to research operations again rather than merely theorize about them. With an empirical data-base, systems analysis would thus have a chance to serve policymakers, and the Republic, much better than it has been able to during recent years. But, unfortunately, there are no strong incentives to undertake the necessary kind of testing. To create the right incentives, in the absence of a formidable enemy in a real war, requires directing attention congressional/executive branch relationships that govern budget allocations.